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CONTENTS

PAGE.

Investigations in the Control of the Potato Tuber Moth, *Gnorimoschema operculella* Zell. (Lepidoptera: Gelechiidae), in North Queensland. By R. C. CANNON .. 107

Bluestain in Hoop Pine Logs. By H. E. YOUNG 125

Bluestained Case Timber and Mould Rots in Hen Eggs. By H. E. YOUNG 141

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THE QUEENSLAND JOURNAL OF AGRICULTURAL SCIENCE

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INVESTIGATIONS IN THE CONTROL OF THE POTATO TUBER MOTH, *Gnorimoschema operculella* Zell. (LEPIDOPTERA: GELECHIIDAE), IN NORTH QUEENSLAND.

By R. C. CANNON, B.Sc.Agr., Entomologist, Science Branch.

SUMMARY.

Studies of the host relationships, seasonal history, and egg-laying habits of the potato tuber moth, experiments in its control in potatoes with DDT and BHC foliage sprays and dusts, and observations on cultural methods of control conducted at Home Hill in northern Queensland during 1946 and 1947 are described.

It has been concluded that the moth does not carry over from season to season in the Lower Burdekin district, and that this is due to the absence of summer-growing cultivated or native Solanaceae. From this it has been inferred that seasonal outbreaks result from introductions with "seed" stocks which, of necessity, are obtained annually from southern districts.

Haulm infestation was effectively controlled by the application of 0·1 per cent. DDT sprays at intervals of up to 3 weeks, and commencing 3 weeks after germination; 2·0 per cent. DDT dusts reduced infestation, but were inferior to sprays.

BHC spray had such a pronounced phytotoxic effect on the plant that its use was discontinued long before the termination of the experiment; when applied regularly, it reduced yields by about 1½ tons per acre. A 4·0 per cent. dust produced less severe injury and was not more effective than the DDT dust.

Tuber infestation was reduced to 7 per cent. or less by regular applications of 0·1 per cent. DDT foliage sprays, and comparable results were obtained with 2·0 per cent. DDT dust.

It is considered that the application of suitable insecticides to the foliage may serve as a useful adjunct to, rather than a substitute for, late hilling in the control of tuber infestation.

INTRODUCTION.

The potato tuber moth, *Gnorimoschema operculella* Zell., occurs in all Queensland potato-growing districts. The larvae attack both foliage and tubers, but the heaviest losses are usually those resulting from direct damage to the tubers. In severe outbreaks, mining in the haulms may be extensive and cause considerable reduction in yield, while in extreme cases and under very dry conditions plants may be completely destroyed.

Considerable attention has been devoted to the problem of tuber moth control. Since most insecticides had proved unsatisfactory, as the larvae are well protected during the period of feeding, control measures in the past have been directed more towards cultural methods designed to provide a mechanical barrier of soil to prevent larvae reaching the underground tubers. The special properties of DDT as a contact insecticide prompted the inauguration of trials with this material for the control of potato tuber moth in tobacco and potatoes. It proved highly effective against this insect in tobacco, almost completely eliminating leaf mining (Cannon and Caldwell, 1946), and, since the present investigations were commenced, has also been reported to be successful in reducing haulm damage in potatoes (Lloyd, 1946).

Of recent years there has been a rapid expansion of potato production on the Burdekin delta, in northern Queensland, and this has been accompanied by some serious outbreaks of tuber moth. In order to escape the high summer temperatures, the crop is grown during the winter with irrigation. Nowhere else in Australia are potatoes grown under comparable conditions, and modifications of established cultural practices have been evolved which are in many respects peculiar to the district. For this reason, it was considered desirable to investigate the problem of tuber moth control with particular reference to local conditions.

SCOPE OF THE INVESTIGATIONS.

The life history of the insect has been studied by a number of workers and is fairly well known. However, it was considered that further information relating to its egg-laying habits, particularly insofar as they relate to tuber infestation in the field, would be desirable. Some attention was, therefore, given to this aspect of the problem. At the same time, an attempt has been made to clarify the seasonal history of the insect and its relation to cultivated and native hosts in the Lower Burdekin district.

The main purpose of the investigations concerned control of the pest in the field, with particular reference to the use of insecticides. An earlier trial had been carried out by Caldwell (1945) with late foliage sprays of DDT; the results indicated that these late sprays were inadequate to cope with a severe outbreak. The work reported here included two large-scale field experiments carried out in 1946 and 1947 with the object of investigating the usefulness of DDT and BHC as foliage sprays or dusts, and the ultimate formulation of a suitable commercial treatment schedule. Cultural practices designed to eliminate or reduce tuber infestation were also studied in the field, but no formal experiments were carried out.

HOST RELATIONSHIPS AND SEASONAL HISTORY.

Before proceeding with a discussion of the problem, the climate of the area will be briefly described, since it has a distinct influence on cropping practices. In tropical northern Queensland, particularly along the coastal belt, there is not the same seasonal differentiation as in temperate regions. Mean temperatures are high, with a seasonal range of only about 15° to 20°F., and frosts are infrequent. On the Burdekin delta mean monthly temperatures range from 65° to 81°F. It is an area of essentially summer rainfall of a monsoonal nature, with a light winter rainfall. The district comes under the influence of the summer monsoons, but does not receive the high precipitations of the more northerly region. The mean rainfall for December is about 4 inches, and the peak is a little over 11 inches in January; thereafter there is a fairly regular decrease to a little over 2 inches in April, and the months May to November have under 2 inches, with an average of about 1 inch per month.

The potato tuber moth, though primarily a pest of potatoes, attacks a number of crops, such as tobacco, tomatoes, cape gooseberry, egg plant and peppers; in addition, many native plants of the family Solanaceae may serve as hosts. None of these is grown extensively during the summer months. Hence, as part of the general programme of investigation, a survey was undertaken to ascertain the nature and distribution of native Solanaceae which might serve as summer hosts of the tuber moth. However, the only native members of this family found at that time of the year were a few large and old specimens of *Physalis minima* and some large specimens of *Solanum torvum*. All plants of these species encountered in the course of the survey were examined for the presence of tuber moth larvae in leaves or stems; there was no sign of mining, and no larvae were obtained from the material. Following the monsoonal rains large numbers of *P. minima* plants appeared in old cultivations, and limited numbers of plants of *Datura* sp. were to be found in sandy deposits left by floods. Young plants of both species were all particularly healthy and showed no evidence of mining. These native species are essentially winter-growing annuals; they disappear during the summer, re-appearing after the rainy season. There are thus no native species persisting through the summer which might serve as hosts for tuber moth after the disposal of winter-grown susceptible crops.

Few insects appear to survive the period of two to three months during the warmest part of the year. It follows, therefore, that introductions from some outside source may be responsible for the initiation of seasonal outbreaks in autumn. In view of this conclusion, attention was next turned to the condition of "seed" supplies entering the district.

In 1945 a large consignment was heavily infested with tuber moth, and most farmers received a quota from this source, so that it was more or less uniformly distributed about the district. It is probably no coincidence that in this season the worst outbreak of tuber moth for many years occurred, when it was estimated that at least 30 per cent. of the crop was unmarketable on account of tuber infestation. Here, at least, was circumstantial evidence of "seed" in relation to tuber moth outbreaks, sufficient to warrant attention in subsequent seasons.

In 1946 most of the "seed" appeared to be free of tuber moth, but a consignment of the variety Bismarck, received about May, would not have been classed as heavily infested. Seven bags, taken at random, were obtained from this consignment for Departmental plantings, and were subjected to close scrutiny whilst being held pending planting. About the middle of May it was observed that moths were numerous, and one bag was emptied and picked over. From this sample 110 intact pupae were collected and 100 per cent. emergence resulted; apart from this, many pupae were damaged and about 100 or more pupating larvae were noted. Allowing for adults which had already emerged, it was estimated that each bag would harbour at least 300 individuals. Based on the relationship of temperature to rate of development in this species (Atherton, 1936; Attia and Mattar, 1939), it was calculated that, under local climatic conditions, two more generations would be produced by the end of August, making three generations within the life of a crop in the field. It is, therefore, evident that populations of considerable magnitude might easily arise from introductions with "seed," even though it might not be particularly heavily infested.

It was not possible to pay the same attention to other portions of this consignment, but many of them were traced. Generally speaking, the incidence of tuber moth in 1946 was light, severe outbreaks being to a large extent localized. However, it is significant that these outbreaks, often widely separated, all occurred in crops grown from this particular batch of Bismarck "seed," or in crops growing adjacent to plantings of the "seed."

In 1947 an effort was made to check the condition of "seed" supplies as they arrived, and samples of most consignments were examined; very few were entirely free of tuber moth, and some were heavily infested. Subsequently, the pest was active fairly early in the season and only a few crops, including those which had received foliage sprays of DDT, escaped early haulm damage. It is also rather significant that one farmer, who had treated a heavily infested batch of "seed" with DDT before planting, had no appreciable haulm damage in his crop. Towards the end of the season moths were very prevalent, though rather less numerous than in 1945.

The evidence so far accumulated, and presented herein, all points to "seed" as the main source from which fresh populations originate each season in the Lower Burdekin district. Consequently, it is considered that high moth populations might be avoided by strict attention to the condition of "seed" stocks secured for district plantings. It is admitted that the detection of eggs, or early larval activity, is extremely difficult, if not impossible, in farm practice. Hence, it becomes necessary to take additional precautions by having all "seed" destined for use in the district treated in the district of origin with a suitable insecticidal dust.

EGG-LAYING HABITS IN RELATION TO CONTROL IN THE FIELD.

Most workers who have studied the life history of this insect on potatoes have stated that eggs are usually laid on the under-surfaces of leaves, or on the petioles and stems. No reference has been found to oviposition on the

ground, or on exposed or covered tubers in the field. On the other hand, Atherton (1936), working on tobacco in northern Queensland, stated that eggs are usually deposited on the surface of the soil near the base of the plants, rather than on the plants themselves. This has an important bearing on control measures, for, if eggs are laid elsewhere than on the plant, complete control could not be achieved by foliage treatment alone.

In the laboratory, a small cage was set up containing fresh potato haulms protruding through a shallow tray of soil, and into this were introduced about 50 moths of both sexes, the females thus having a choice of oviposition sites. After a few days the haulms and soil were examined, and eggs were found on leaves, petioles and stems, usually in somewhat protected situations adjacent to leaf veins, or in grooves of the petioles and stems, but none was found on the loose soil when it was examined undisturbed nor after it was raked over.

In the field, large numbers of moths have been observed sheltering during the day under small clods, leaves and other debris, but in no case were eggs found in these situations. Late in the afternoon the moths leave these hiding places and a period of flight ensues, after which they settle on the foliage. Thereafter they remain quiescent and it is presumed that eggs are laid at that time. On examining plants taken from the field during flight periods, eggs have been found on the foliage, frequently partly obscured by hairs.

In order to discover whether egg-laying moths might be attracted to tubers in the field, a number of developing tubers near the surface were exposed during a period of peak moth activity, but before the haulms had commenced to die off. After several nights' exposure these tubers were removed and examined, but no eggs were found. Hence it has been concluded that exposed tubers are less attractive than green foliage.

Studies in the field further revealed that larvae will continue to feed in the leaves as long as they remain green and rarely desert their original mines until fully fed. Under these conditions, larvae which have been operating in the upper leaves frequently pupate on the foliage near the mine. Larvae in the lower leaves, particularly if they are actually touching the ground, usually leave the plant and enter the soil through a protective silken tunnel and pupate near the surface. As the leaves begin to die off, larvae forsake their mines and move downwards along the stem; older larvae may pupate, but the younger ones enter at leaf axils and re-commence feeding, often reaching the stems. In the later stages of plant senescence large numbers of larvae may be seen escaping from mines and moving downwards until they reach the ground, where they wander about and eventually burrow into the soil. Older larvae, no doubt, commence pupation, while many of the younger ones succeed in reaching tubers, where they can resume feeding.

These observations support the view, implied by other workers, that the moth will not oviposit on the soil provided there is healthy, green foliage available. They are in agreement with Graf's (1917) statement that "the

larva does not prefer to feed on the tubers in the ground as long as the potato tops are green and succulent.'' It is inferred, however, that direct infestation of tubers may take place after the haulms cease to be sufficiently attractive. It is fairly evident that tuber infestation is largely the result of migration of larvae from the haulms after the onset of senescence. Hence, field control should be designed to reduce breeding on the foliage and to provide a mechanical barrier capable of preventing migrating larvae from gaining access to tubers in the ground.

EXPERIMENTS WITH FOLIAGE SPRAYS AND DUSTS FOR TUBER MOTH CONTROL.

The object of these experiments was to investigate and compare the efficacy of DDT and BHC in controlling tuber infestation, when applied to the foliage of potato plants. The accumulated evidence from various sources, including the work on tobacco previously mentioned, had already indicated that DDT might reasonably be expected to control haulm infestation. The studies on egg-laying habits of the insect had not been undertaken when the first of these experiments was planned, and the extent to which haulm infestation might be related to tuber infestation was still in doubt. In the event of either of the insecticides proving effective, it was desired to secure sufficient data for the formulation of treatment schedules, and provision was made for investigating—

(1) a range of treatments over the growing period of the crop to determine the starting point for the application of control measures; and

(2) the maximum interval between applications commensurate with adequate economic control.

Both experiments were of essentially the same design; some modifications were introduced into the 1947 experiment in view of the results obtained from the 1946 experiment. They were conducted at Home Hill on different farms and were included among the later plantings so that they would encounter the higher moth populations which are characteristic of these late plantings.

Design of the Experiments.

In both experiments the design involved split-plots, with main-plots comprising ranges and frequencies of application arranged factorially. These were subdivided into the requisite number of sub-plots to accommodate the types and forms of insecticide included for trial.

Potatoes were planted in rows 3 ft. 6 in. apart and the ''seed'' spaced 12 inches apart. Sub-plots were 6 rows wide and 32 ft. long, with buffer strips 5 ft. wide at the ends and separating the sub-plots. In order to reduce interference between treatments due to wind drift of insecticides, particularly the dusts, only the inner four rows of each plot were treated. As a further precaution against border effects, only the two inner rows were taken in

computing data on infestation and yield. The plot units from which data were obtained were thus approximately 1/200 acre in area. The whole area of experiments exceeded 1 acre each.

In both experiments the main-plot treatments were identical; they comprised 3 ranges and 2 frequencies of application, as follows:—

Ranges of Application.

R1—First application made 3 weeks after germination.
R2—First application made at a stage corresponding to the initiation of flowering, estimated at 5 weeks after germination.
R3—First application made immediately after flowering, and about 2 weeks after R2.

Frequencies of Application.

F1—Applications made at 2-weekly intervals.
F2—Applications made at 3-weekly intervals.

Factorial arrangement of the two groups gave 6 combinations, which constituted the main-plots. There were 3 replications in the 1946 experiment, and 2 replications in 1947.

Sub-plot treatments differed as between the two experiments; details are given separately hereunder.

Sub-Plot Treatments in Experiment No. 1 (1946).

The plan provided for the inclusion of DDT and BHC as sprays and dusts. In view of the toxicity of BHC to tobacco, and the botanical relationship of the two crops, there was reason to expect that it might have a similar effect on potatoes. However, as no opportunity was afforded for carrying out a phytotoxicity test in advance of the main experiment, BHC was included, with provision for its replacement should undesirable symptoms appear. The original sub-plot treatments were:—

S1—DDT mayonnaise emulsion spray containing 0·1% p-p isomer of dichloro-diphenyl-trichloroethane.*
S2—BHC mayonnaise emulsion spray containing 0.2% gamma isomer of benzene hexachloride.†
D1—DDT-pyrophyllite dust containing 2.0% p-p isomer.‡
D2—BHC-pyrophyllite dust containing 0.4% p-p gamma isomer.‡
C—Control; untreated.

Within a week after the first application, a pronounced phytotoxic effect was observed following the BHC spray; the same effect, in a milder form, was

* Prepared from "Pespruf 20," a proprietary mayonnaise emulsion containing 20 per cent. of the p–p isomer of dichloro-diphenyl-trichloroethane.

† Prepared from "E.F. 488M," an experimental mayonnaise emulsion containing 1·95 per cent. of the gamma isomer of benzene hexachloride, supplied by Imperial Chemical Industries of Australia and New Zealand Ltd.

‡ Prepared from impregnated pyrophyllite dust containing 10 per cent. of the p–p isomer and 1·3 per cent. of the gamma isomer, respectively.

associated with the dust. Accordingly, the BHC spray was replaced by a 0.2% DDT spray in the R2 and R3 series. In the R1 series the second application was made with 0.2% DDT, but subsequent applications reverted to the original BHC spray, with the object of obtaining some data on its influence on yield.

Sub-Plot Treatments in Experiment No. 2 (1947).

In view of the phytotoxicity of BHC already mentioned, the only insecticide retained in this experiment was DDT, and it was restricted to one level each of spray and dust. In the meantime, consideration had been given to the inclusion of a fungicide to control target spot (*Alternaria solani*), which has been of considerable importance from time to time. In view of the suspected interference of copper compounds with the toxicity of DDT, as well as for other considerations, a copper fungicide was included in a factorial arrangement of 6 sub-plots, as follows:—

S1—DDT mayonnaise emulsion spray containing 0.1% p-p isomer of dichloro-diphenyl-trichloroethane.*

S2—DDT-pyrophyllite dust containing 2.0% p-p isomer.*

C1—Control; untreated.

D1—DDT spray as for S1, plus 0.17% copper as copper oxychloride.†

D2—DDT dust as for D1, plus 10.0% copper as copper oxychloride.‡

C2—Fungicide only; spray of 0.17% copper as copper oxychloride.†

Field Notes on Experiment No. 1.

The area was fertilized and planted with the variety Brownell on June 17, 1946; the first plants appeared above ground on July 11, though germination was not complete until about July 24. The first hilling was carried out on August 4, following which the crop was irrigated at intervals of 4 to 9 days, receiving a total of about 16 inches of water. The crop made exceptionally good top growth and was harvested on October 10, 16 weeks after planting.

As already mentioned, tuber moth was not severe in 1946 and very few moths were encountered on the farm where the experiment was established. In the experiment proper no moths were observed until the last few weeks and even then only odd individuals were seen on the wing in the late afternoon. Haulm mines were almost entirely absent, even when the crop was mature, though a few may have been overlooked at this late stage.

The first insecticide application was made on August 10 and the schedule followed as planned, with variations of not more than a day in the intervals prescribed. Sprays were applied with a knapsack sprayer in sufficient quantity

* Prepared from the same materials used in Experiment No. 1.

† Prepared from "Cuprox," a proprietary dispersible powder containing 50 per cent. copper as copper oxychloride.

‡ Prepared from "Smutol," a proprietary fungicidal dust containing 50 per cent. as copper oxychloride.

to thoroughly wet the upper surface of the foliage, the average rate of application being 100 gallons per acre. Dusts were applied with a bellows type knapsack duster at a rate of 20 to 30 pounds per acre. There was a noticeable drifting of dusts across the plots, but it was considered that the small dust deposit reaching plots for which it was not intended could not have materially interfered with the designed treatments.

Field Notes on Experiment No. 2.

The experimental area was not planted as a separate unit, but as part of the whole field of 20 acres of potatoes. A mechanical potato planter, which applied fertilizer at the same time, was used. The field was planted with the variety Brownell on May 15, 1947; germination commenced on June 10 and was more or less complete by June 17. The crop received the initial hilling on July 9, and was irrigated at regular weekly intervals thereafter, receiving a total of about 12 inches. It made fair top growth, but was by no means as vigorous as the 1946 crop. It was remarkably free from leaf-roll and target spot, for the control of which fungicides had been included in this experiment.

The incidence of tuber moth was much greater than in the previous season; the pest was widely distributed and haulm damage was observable within the first 3 weeks after germination. The crop, with the exception of the experimental section, was promptly sprayed with 0.1% DDT and copper oxychloride. This had the effect of reducing the over-all population in the field, but did not appear to materially influence the experimental strip. Moths were still present there in relatively large numbers, and haulm injury was evident, particularly in the control plots and the untreated border rows. Conditions in 1947, therefore, provided a more severe test of the treatments than they did in 1946.

The application of insecticides and the fungicide, using the same equipment as in 1946, was commenced on July 15, 4 weeks after germination. Rainy and windy conditions were encountered at times, and interfered with the regular schedule of treatments. The actual dates of application are shown hereunder:—

Date of Application.	R1.		R2.		R3.	
	F1.	F2.	F1.	F2.	F1.	F2.
July 15	x	x				
July 29	x		x	x		
August 6		x				
August 12	x		x		x	x
August 25	x	x	x	x	x	
September 2						x

The greatest departure from the schedule occurred with the second application of R2F2, in which the interval was 27 days, due to bad weather during the period August 18-23.

PHYTOTOXIC EFFECTS OF BHC.

BHC, as spray and dust, was included only in Experiment No. 1 and within a week of the first application a marked effect on the foliage of BHC-sprayed plots was noticeable, it being possible to distinguish affected plots from a distance. There was a yellowing of the foliage, with thickening and curling of leaves, somewhat reminiscent of the symptoms associated with leaf-roll. Later, dark necrotic lesions developed, eventually destroying a large part of the total leaf surface. When the spray was withheld subsequent growth was quite normal, but the symptoms reappeared when spraying was resumed. In the case of the dust, symptoms were less severe, but otherwise similar to those produced by the spray. This reaction to BHC was not entirely unexpected in view of the experience with tobacco (Cannon and Caldwell, 1946), where the symptoms were not unlike those in potatoes.

Spray injury was so severe that it was evident that yields would be adversely affected if the application of the spray was continued. As the dust was so much less drastic in its action it was retained, but, for the second application, a 0·2 per cent. DDT spray was substituted for the BHC spray. Before the next application, however, it was decided to revert to the original BHC spray in the R1 series only, so as to secure some data relative to its effect on yield. In this series, therefore, except for the substitution of DDT in the second application, plots received BHC spray at the prescribed intervals. Table 1 sets out data on yield relative to BHC-sprayed plots and those not so treated.

Table 1.

Mean Yields in BHC-Sprayed Plots and Groups of Plots Otherwise Treated (Expressed as Tons per Acre of No.1 Grade Potatoes).

——	Control.	Mean of S1, D1, D2.	S2.
Mean Yield of Plots	6·39	6·62	4·94
Other Treatments less S2	1·45	1·68	..
S.E. of Difference	±0·40	±0·36	..

The above differences are significant at the 1 per cent. level. The application of BHC spray was responsible for yield depressions of the order of 1½ tons per acre.

Though foliage injury induced by the dust was less severe, there was undoubted evidence of toxicity, and this disposes of any suspicion that emulsifying agents in the spray, rather than the BHC itself, may have been responsible for the condition. The materials used were based on a commercial product consisting of a mixture of isomers, and containing only 13 per cent. of the gamma isomer. Since the mixture of isomers is involved, it is not clear whether all four isomers are equally toxic, and the point will remain in doubt

until the pure gamma isomer is tested. In the meantime, BHC products at present available, containing a mixture of alpha, beta, gamma and delta isomers, are out of the question for use on potatoes.

INFLUENCE OF DDT ON YIELD.

In neither experiment was there the slightest indication of foliage injury associated with the application of DDT, even where the concentration in the spray was increased to 0·2 per cent. in some series in Experiment No. 1. Appropriate yield data for the two experiments are given in Table 2. In Experiment No. 2 the yields are means of plots with and without the copper fungicide.

Table 2.

Mean Yields in DDT-Treated and Control Plots in Experiments Nos. 1 and 2 (Expressed as Tons per Acre).

	Experiment No. 1.		Experiment No. 2.	
	Grade 1.	Grades 1 and 2.	Grade 1.	Grades 1 and 2.
0·1% DDT Spray	6·39	7·10	3·33	4·21
2·0% DDT Dust	6·90	7·69	3·32	4·17
Control	6·39	6·77	3·20	4·11
0·2% DDT Spray	6·64	7·45	*	*

* The means are based on yields of plots in R2 and R3 series only and are not subject to the same tests of significance as the other data.

The only significant difference is that between dusted and sprayed or control plots in Experiment No. 1, and that is just equal to the difference necessary for significance at the 5 per cent. level. The yields of treated plots were in all cases equal to, or better than, those of control plots, and it may be concluded that DDT did not significantly reduce yields.

EFFECT OF FOLIAGE TREATMENT ON HAULM INFESTATION.

During the course of Experiment No. 1 moth populations were extremely low and no measurable haulm infestation was encountered during the growing period. It is possible that a few mines may have been commenced at a late stage and were overlooked. In the second experiment the pest was much more prevalent and haulm mines were in evidence within 3 weeks after germination. The extent of this was assessed on August 22, about a fortnight after flowering, and following the initial post-flowering insecticide application. Ten plants more or less in the centre of each plot, taking 5 consecutive plants in each of the two datum rows, were examined. Subject to certain limitations, due to the coalescence of some mines and the overlooking of others, the number of larval

mines for each group of 10 plants was recorded, and used as a measure of infestation. In order to restrict all observations to the one day, two groups only of the plots were assessed in this manner, namely—

(*a*) all plots in the R1 series, for determination of the effects of the several insecticides; and

(*b*) sprayed plots only in all series, for evaluation of the effects of varying treatment schedules.

Table 3 sets out the sub-plot data from series R1, and Table 4 those relative to treatment schedules with the DDT sprays.

Table 3.

Tuber Moth Infestation of Haulms in Series R1 (Expressed as Mean Number of Mines per 10 Plants).

Insecticide.	Without Copper.	With Copper.	Mean.
0·1% DDT Spray	16·8	12·0	14·4
2·0% DDT Dust	165·5	162·2	163·9
Control	206·5	236·5	221·2
Mean	136·7	129·6	133·2
Difference for significance at 5% level			41·6

It is clear that DDT spray was highly effective in reducing haulm infestation to very small proportions. Although the dust did exercise some control over infestation, it did not reduce it to a level comparable with that of the spray. It is equally apparent that the inclusion of the copper fungicide had a negligible influence on the effectiveness of the DDT.

Table 4.

Tuber Moth Infestation in DDT-Sprayed Plots in all Series (Expressed as Mean Number of Mines per 10 Plants).

Treatment Schedule.	Applied 2-Weekly.	Applied 3-Weekly.	Mean.
Commenced 2 weeks before flowering ..	20·5	8·2	14·4
Commenced immediately before flowering ..	17·5	51·2	34·4
Commenced immediately after flowering ..	74·5	94·2	84·4
Mean	37·5	51·2	44·4
Difference for significance at 5% level			36·2

The only significant difference occurs between the three ranges of treatment, where R1 and R2 are both definitely superior to R3. This is understandable in the light of the outbreak to which the trial was subjected, as populations had reached a relatively high level before applications in the

latter series were commenced. It is fairly certain that haulm infestation can be controlled with DDT, at least as a spray, provided treatment commences at the first sign of infestation, judged by the presence of mines in the lower leaves. The differences between 2-weekly and 3-weekly schedules are not significant, so that there is probably little to be gained by reducing the interval between treatments to less than three weeks.

EFFECT OF FOLIAGE TREATMENT ON TUBER INFESTATION.

Immediately after harvesting, the tubers were examined for tuber moth larvae or evidence of their presence. Free and infested tubers from each plot were counted and weighed, taking into account grades 1 and 2, but discarding chats. Previous work at Ayr had demonstrated a close correlation between tuber infestation estimates based on numbers and weights, and, for the purposes of this report, infestation percentages have all been calculated on a weight basis, in terms of total yields of grades 1 and 2. For statistical analysis individual plot percentages have been transformed to degrees by the inverse sine transformation, and comparisons made in terms of the transformed variate.

In both experiments infestation of treated plots was significantly less than that of controls, though infestation of the latter was itself relatively low. This was to be expected in Experiment No. 1, where the general population level was low, but is not so easily explained in the case of Experiment No. 2. Both crops were grown under ordinary commercial conditions; they were subjected to the usual cultural practices followed in the district and applied at the discretion of the farmer concerned. The experiments were carried out on farms owned and farmed by the same man, who regularly applied rather drastic hilling with the object of reducing tuber infestation. It would appear that this measure, in itself, reduced infestation in both instances to a level of about 10 per cent., irrespective of foliage treatments, as shown by the results of controls.

The results are in distinct contrast to those based on haulm infestation in Experiment No. 2, where DDT-sprayed plots were, for all practical purposes, free of tuber moth, while the controls were heavily infested. As mentioned earlier, large numbers of larvae migrate to the ground during haulm senescence, and it has been concluded that these are primarily responsible for tuber infestation. However, the fact that in Experiment No. 2 about 6 per cent. of the tubers in plots virtually free from haulm infestation were affected would suggest that migrating larvae are not entirely responsible for the infestation of tubers. It might be argued that larvae could conceivably move across from untreated rows, but the presence of treated buffer rows adjacent to the datum rows would, it is considered, preclude this possibility. It seems more likely that gravid females reaching datum rows at or near maturity might, in the absence of green foliage, oviposit at the base of plants or on exposed tubers, though such behaviour has not actually been observed.

Table 5.

Tuber Infestation of Sub-Plots (Expressed as Sub-Plot Means in Terms of Percentages and Degrees).

	Percentage Infested.		Degrees.	
	Exp. No. 1.	Exp. No. 2.	Exp. No. 1.	Exp. No. 2.
4·0% BHC Dust	7·5	..	15·3	..
0·1% DDT Spray	4·1	7·0	11·1	14·2
2·0% DDT Dust	6·5	8·9	14·3	16·8
0·1% DDT Spray plus Copper ..	..	6·1	..	13·8
2·0% DDT Dust plus Copper	..	6·7	..	14·3
Copper Spray	..	8·7	..	16·9
Control	9·9	11·3	18·0	19·4
Difference for Significance at 5% level	*	*	2·6	3·3
Mean Treated	6·0	7·5	14·3	15·2
Control	9·9	11·3	18·0	19·4
Difference for Significance at 1% level	*	*	2·9	3·5
Mean DDT Spray	*	6·6	*	14·0
Mean DDT Dust	*	7·8	*	15·5
DDT with Copper	*	6·4	*	14·0
DDT without Copper	*	7·9	*	15·5
Difference for Significance at 5% level	*	*	*	2·4
0·2% DDT Spray	*	5·0	*	12·6

* The infestation is based on plots in R2 and R3 series only, and the figures are not subject to the same tests of significance as the other data.

In Experiment No. 1, the 0.1% DDT spray was significantly better than the DDT or BHC dusts, but in Experiment No. 2 DDT sprays were only slightly better than the dusts, whether taken separately or grouped. This result is in close agreement with that obtained when using DDT sprays and dusts against the same insect in tobacco (Cannon and Caldwell, 1946). It was then suggested that the sprays may have possessed slightly superior residual properties. Another point to consider, however, is the possibility of providing equivalent control by increasing the concentration of DDT in the dust.

Since it has already been shown that BHC is toxic to the potato plant, and that copper oxychloride spray alone is distinctly inferior to DDT in reducing tuber infestation, the main plot data have been calculated from DDT-treated sub-plots only. Thus, in Experiment No. 1 only sub-plots S1 and D1 were used, and in Experiment No. 2 main-plot data are based on sub-plots S1, S2, D1 and D2 only.

Table 6.

TUBER INFESTATION OF MAIN-PLOTS (EXPRESSED AS SUB-PLOT MEANS IN TERMS OF PERCENTAGES AND DEGREES).

Treatment Schedules.	Percentage Infested.		Degrees.	
	Exp. No. 1.	Exp. No. 2.	Exp. No. 1.	Exp. No. 2.
R1F1	3·4	6·2	10·1	13·7
R1F2	4·7	4·6	12·3	12·0
R2F1	4·3	6·6	10·5	14·2
R2F2	5·6	8·4	13·5	16·0
R3F1	7·1	6·7	15·1	13·9
R3F2	6·7	10·6	14·5	18·8
Difference for Significance at 5% level	..	..	5·4	4·1
Commenced 2 weeks before flowering..	4·1	5·4	11·2	12·9
Commenced just before flowering ..	5·0	7·5	12·0	15·1
Commenced after complete flowering ..	6·9	8·6	14·8	16·4
Difference for Significance at 5% level	..	..	3·8	2·9
2-weekly applications	5·0	6·5	11·9	14·0
3-weekly applications	5·7	7·9	13·5	15·6
Difference for Significance at 5% level	..	..	3·1	2·4

In both experiments the R1 schedule, with applications commencing 2 weeks prior to flowering, was significantly better than R3, commencing after flowering, and the R2 schedule was intermediate, but not differing significantly from either of the others. A 3-weekly interval between applications was not significantly inferior to a 2-weekly interval, except in the R3 series in Experiment No. 2 where, as already mentioned, haulm infestation had reached considerable proportions before any insecticide was applied.

OBSERVATIONS ON CULTURAL METHODS OF CONTROL.

When these insecticidal investigations were undertaken it was intended to carry out field trials with cultural methods of control, but, as circumstances did not permit the establishment of suitable experiments, studies were limited to examination of existing practices. Life history studies led to the conclusion that the critical stage for tuber infestation occurs during the period of haulm senescence, when the provision of an adequate soil barrier becomes imperative.

In the Lower Burdekin district it has been the usual practice to commence hilling somewhat earlier, for a number of reasons. Quite apart from the question of tuber moth control, relatively early hilling is a natural accompaniment of the construction of deep inter-row irrigation furrows. Under local conditions these furrows are necessary, though they might be less deep if the ground was suitably graded, but it is considered that they should be prepared with the minimum

movement of earth towards the plants. With the vigorous top growth of crops it is also desirable that some soil should be thrown towards the plants to give support to the haulms, which would otherwise sprawl across the furrows and be damaged by late hilling.

Even with a row spacing of 39 to 45 inches, which is greater than that usually allowed elsewhere, it has been found that the hill is rather unstable and tends to weather down with the passage of time. In any case, in most varieties, with the possible exception of Bismarck, tuber-forming stolons tend to extend upwards and outwards, until they are relatively close to the soil surface, before tuber enlargement takes place, and early hilling tends to encourage the formation of tubers further from the main stem. These disadvantages have been partly overcome by repeating the operation, so that it has become one of progressive hilling. One of the disadvantages of this is that the final hill, required at the most critical stage, is even more unstable.

In practice, the method of progressive hilling has achieved some control of the pest; but, based on control plot data from the field experiments, it has not reduced tuber infestation below about 10 per cent. It has, therefore, been concluded that existing practices might, with advantage, be modified by reducing pre-flowering hilling and concentrating on more drastic hilling at the onset of haulm senescence. Such modifications were adopted by a few growers in 1947, and it is considered that their results fully justified the measures.

GENERAL DISCUSSION OF RESULTS.

Field studies associated with these investigations have led to the interesting conclusion that tuber moth may not survive from season to season in the Lower Burdekin district. It is explained by the fact that cultivated and native Solanaceous plants in this region are almost entirely winter-growing annuals, which though present during the potato-growing season are virtually absent in the summer months. In some respects the problem of control is therefore simplified, since there is no established local population of any size to contend with at the beginning of each potato season. With the recent re-introduction of tobacco growing in the district, and its probable rapid expansion, the position is likely to be modified, since this crop is susceptible to attack and would be in the field during part, if not all, of the summer. However, control of this species in tobacco is essential and can be achieved very effectively by the use of DDT, and it is unlikely that any large population would be allowed to survive on this crop, except on stalks abandoned after harvesting.

Due to the presence in the district of *Myzus persicae* Sulz., a vector of the potato leaf-roll virus, it is generally accepted that the production of "seed" locally is out of the question, quite apart from any consideration of the difficulty of holding "seed" for as long as six months. Hence, it is inevitable that fresh stocks of "seed" must be drawn from southern districts each season. In order to avoid, or at least reduce, the risk of introducing nucleus populations of potato tuber moth, as probably no potato-growing district in Australia is

completely free from the pest, it is considered that such "seed" should be treated with a suitable protective dust in the district of origin as soon as possible after harvesting.

Field studies, combined with the results of the two field experiments, have led to the conclusion that tuber infestation in the field is usually initiated by larvae migrating from senescent haulms. Hence, it has been inferred that destruction of larvae attacking the foliage will, to a very large extent, control tuber infestation. On the other hand, it is probable that egg-laying takes place on the ground or on exposed tubers after the haulms cease to be attractive to egg-laying moths. Complete control of the insect in potato crops does not entirely eliminate sources of late infestation, since it is possible that moths from neighbouring patches of susceptible weeds might reach the field and oviposit at the base of plants. Therefore, other methods of control, such as late hilling, need to be considered in conjunction with insecticidal methods.

The phytotoxicity of BHC spray to the potato plant was so pronounced, and the yield depression of 1½ tons per acre so great, that this insecticide must for the present be abandoned for use on potatoes. In these experiments, where a comparison between 4 per cent. BHC dust and 2 per cent. DDT dust is afforded, the two dusts exhibited about equal toxicities to tuber moth. Therefore, should it eventually prove that the phytotoxicity of the crude product is not a property of the gamma isomer, and if products consisting of the pure gamma isomer are later produced commercially, consideration may have to be given to further trials with that insecticide.

In considering the effect of copper compounds on the toxicity of DDT to insects, reference to Tables 3 and 5 reveals that the inclusion of copper oxychloride had no appreciable effect on the toxicity of DDT. This is particularly interesting in view of the conclusion of Common (1947) that the addition of copper carbonate or copper oxychloride to DDT-pyrophyllite dusts reduced their toxicity to *Heliothis armigera* Hbn. The relative susceptibility of the two insects to DDT may, in part, explain the different experimental results. Though copper oxychloride spray alone did not reduce haulm infestation, it did reduce tuber infestation below that of controls. To an extent this is in agreement with the finding of Atherton (1936), that the application of cuprous oxide emulsion sprays reduced *G. operculella* infestation of tobacco seed-beds. Within a few weeks of harvesting it was observed that plots which had received sprays containing copper were slightly greener than the rest, though the difference was by no means clear-cut. This may, however, provide an explanation of the slight reduction in tuber infestation in that the foliage of such plots would be attractive to moths for a slightly longer period, thereby reducing oviposition on the ground, where hatching larvae would be less likely to come in contact with any insecticide residues.

In Experiment No. 2 there is a fairly close relationship between the control of haulm infestation and the control of tuber infestation by DDT applications. This is very much what would be expected in the light of the earlier conclusion that the bulk of tuber infestation results from the migration

of larvae from the haulms. In this experiment the best results were obtained with applications commencing within three weeks of germination. It is considered that this was to a large extent related to the fact that infestation in the field commenced at about this time. Quite obviously, little benefit could be expected from commencing treatment much in advance of the appearance of the pest in the crop. It would seem then that the foliage treatment should be applied at the inception of an outbreak, and might safely be delayed until such time as this occurred. It has also been clear that the interval between successive applications may be extended to 3 weeks; but, since the experiments were not designed to investigate longer intervals, some doubt still exists as to whether the interval might not be further prolonged. There has been evidence, apart from these experiments, which would suggest that applications might be more widely spaced, even to the point of relying on a single application coincident with the first indication of an outbreak.

The evidence of both experiments indicates that complete control of tuber infestation cannot be achieved by foliage treatment alone, effective though it may be. This means that cultural measures, such as late hilling, still have a place in the programme of tuber moth control. Foliage treatment is, however, so effective that the same strict attention to cultural measures as heretofore is not necessary. Taking everything into consideration, there is reason to believe that infestation of tubers may be reduced to very small proportions by the use of a DDT foliage spray combined with late hilling. It is recommended that the insecticide be applied at the first indication of an outbreak, and the application repeated only when haulm infestation shows signs of increasing.

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REFERENCES.

Atherton, D. O. 1936. Leaf miner and stem borer of tobacco in North Queensland. Qld. Agric. J. 45: 12-31, 131-45, 239-48, 331-44.

Attia, R., and Mattar, B. 1939. Some notes on "The Potato Tuber Moth." Minist. Agric., Egypt, Bull. 216.

Caldwell, N. E. H. 1945. Unpublished Report to Under Secretary, Queensland Department of Agriculture and Stock.

Cannon, R. C., and Caldwell, N. E. H. 1946. Investigations in the control of the tobacco leaf-miner with DDT and "Gammexane." Qld. J. Agric. Sci. 3: 96-102.

Common, I. F. B. 1947. Unpublished Report to Under Secretary, Queensland Department of Agriculture and Stock.

Graf, J. E. 1917. The potato tuber moth. U.S.D.A. Bull. 427.

Jenkins, C. F. H., and Forte, P. N. 1946. 1945-46 experiments with DDT and 666 as agricultural insecticides. J. Dept. Agric. W.A. 23: 307-17.

Lloyd, N. C. 1946. Insecticidal control of potato moth. Agric. Gaz. N.S.W. 57: 229-33.

BLUESTAIN IN HOOP PINE LOGS.

By H. E. YOUNG, D.Sc.Agr., Pathologist, Science Branch, Division of Plant Industry.

SUMMARY.

An account is given of a series of experiments in connexion with the development of bluestain in hoop pine logs. A number of anti-stain treatments are described and the results summarized. It was shown that a commercial ethyl mercury chloride preparation is superior to the other mixtures used in the experiment.

It was further demonstrated that logs left in the rain-forest with the bark on and the ends protected remained in perfect condition.

INTRODUCTION.

Summer losses of hoop pine (*Araucaria cunninghamii*) timber in Queensland due to degrade on account of bluestain were sufficiently great to warrant experiments aimed at finding some means of preventing or at least minimizing these losses and also at acquiring a closer knowledge of the conditions necessary for the development of bluestain.

With these ends in view a series of experiments was designed in co-operation with forestry officers and carried out under normal logging conditions. The work was located at Imbil in the Mary Valley in southern Queensland because of the heavy incidence of bluestain in that locality and because a sawmiller at Imbil was prepared to provide milling facilities for the logs involved in the experiments.

The initial experiments were designed to provide information on the following points:—

(1). The period required for the development of bluestain under field conditions; the site at which infection is most likely to occur (for example, at the tree stump in the rain-forest, at the scrub loading ramps on the rain-forest edge, or in the open); and the effect of position of the logs at the ramps (that is, whether they were on the ground or on skids) on bluestain incidence.

(2). Whether direct contact at the scrub ramps of a clean log with a log affected with bluestain increases the possibility and degree of infection of the clean log.

(3). The value of certain chemical and physical treatments which, while cheap in initial cost and application, were considered likely to prevent or check the development of bluestain.

When the initial experiments revealed that a commercial mercurial fungicide was a promising control agent, a further series of trials was conducted with this material.

The maximum time for which logs are left in the rain-forest or at the scrub ramps because of delays in haulage occasioned by wet weather is about five weeks. The experiments were designed to cover a period of eight weeks from the initiation of each experiment. This gave a wide margin and made it more likely that the logs would experience weather conditions suitable for the development of bluestain. Because weather conditions cannot be foretold accurately it was decided to commence the experiments regardless of the weather obtaining at the time, and if the appropriate conditions conducive to bluestaining, as evidenced by the control logs, did not appear within 14 days, then the experiment was to be repeated.

INITIAL SERIES OF EXPERIMENTS.

Experimental Procedure.

For the purpose of the experiment freshly felled hoop pine logs were essential. "Special" quality logs were not used on account of their high value, nor were "tops" because of the complications involved in making observations, due to the previous entry of bluestaining organisms through old branch stubs and knots. Because of the difficulty of obtaining sufficient "B" class logs concentrated in the one area it was decided that both "A" and "B" class logs should be included in the experiment. The use of short log lengths—for example, three feet—would allow for more replications, but stains penetrating from each end might meet and make any observations of side penetration useless. Also, the high value of full length timber would be lost. Accordingly full-sized logs were employed. The logs varied in length from 16 feet to 29 feet with an average length of 23 feet and an average centre girth of 58 inches. These logs were utilized for normal milling purposes on the completion of the experiment.

With the object of gaining a measure of the penetration of the bluestain, the logs when milled were sawn longitudinally down the centre, the cut being made in the vertical plane in relation to the position of each log during the experiment. The edges of the cut surfaces were then smoothed with a hand plane (see Plate 1) in order that the staining might be more easily seen. The depth of stain penetration was measured at intervals of one foot along the length of the log on both top and bottom sides; all measurements were commenced from the butt end. Owing to inaccuracies introduced by end penetration separate figures were taken out for two feet at each extremity of the log; this left the remaining data for the bulk of the log to give an accurate representation of the side penetration of the log by the stain.

Means were taken out for each individual log for the maximum penetration along the top and bottom surfaces of the length of the log and for the two ends, thus enabling a comparison to be made. The means for all the logs with the same treatments were then assessed. Measurements were made to one-tenth of an inch; the first one-tenth from the outside was disregarded as being liable to confusion with discolouration due to weathering. For the purpose of easy reference all measurements for each log were then averaged and a figure obtained indicative of the relative staining of each log. In practice this figure was found to be well correlated with the detailed figures for each log.

Plate 1.

Planing Surface of Flitch of an Experimental Hoop Pine Log at the Sawmill in Order to Measure Bluestain Penetration.

The weather conditions obtaining during the experiment are detailed in an appendix.

Period and Amount of Bluestain Development in the Rain-forest.

For this experiment 22 logs were available. These were barked and left lying in the rain-forest at the stump where they fell. They were milled after various predetermined periods as shown in Table 1. The logs were cut as described and the amount of stain penetration measured.

Table 1.

Stain Penetration in Logs at the Stump at Weekly Intervals after Felling.

No. of Logs.	Weeks from Felling to Milling.	Mean Depth of Stain Penetration (Inches).						Overall Mean.
		Under Surface.	Upper Surface.	Butt Under.	Butt Upper.	Top Under.	Top Upper.	
1	2	0	0	0	1·0	1·2	0	0·36
2	3	0	0	0·4	0·9	0·4	0·6	0·38
3	4	0·2	0·5	0·7	1·0	0·9	0·9	0·7
4	5	0·2	0·3	2·0	1·2	0·4	1·7	0·96
4	6	0·3	0·6	0·6	0·8	0·4	0·7	0·6
4	7	0·5	0·6	1·8	1·5	1·8	1·8	1·3
4	8	0·7	0·9	3·1	3·2	1·3	0·8	1·6

From Table 1 it is seen that under the conditions obtaining during the experiment staining does not reach serious proportions in logs left lying in the rain-forest until the fourth week, when penetration from the sides along the length of the log becomes evident. This is probably due to the slow drying of the logs under the humid shaded rain-forest conditions, where wood remains at a high moisture content for a long time and does not permit the growth of aerobic organisms until a considerable period has elapsed.

End penetration commenced more rapidly owing to the faster drying out of the ends in relation to the sides; and the penetration was deeper because the fungi concerned, not being cellulose destroyers, find it easier to follow the course of the vessels than to cross them. The upper sides of the logs tended to stain more than the lower, though the difference was small. There was no staining difference between butt and top ends of the log. At the time of milling the ends of all the logs except those exposed for two weeks showed an external discolouration of the sapwood. In no cases was the heartwood discoloured either internally or externally. The surface discoloration was also evident on the longitudinal surface of the log.

Period and Amount of Bluestain Development at the Scrub Ramps.

For this experiment, 12 logs were available. Six were placed on the ground at the loading ramps on the edge of the rain-forest, whence they had been hauled from the stumps in the usual routine fashion, and six were raised off the ground on skids allowing ventilation beneath the logs. The results shown in Table 2 indicate that the logs on the ground were somewhat more

Table 2.

Mean Depth in Inches of Stain Penetration in Logs Stored at the Scrub Ramps on the Ground and on Skids.

Position.	Weeks from Felling to Milling.	Mean Depth of Stain Penetration (Inches).						Mean.
		Under Surface.	Upper Surface.	Butt Under.	Butt Upper.	Top Under.	Top Upper.	
On Ground	3	0	0	0	0	0·2	0	0·03
	5	3·3	2·4	3·7	3·1	2·9	2·8	3·0
	6	0·2	1·4	0·7	2·8	2·2	1·6	1·5
	7	0·9	1·1	2·8	3·0	2·6	3·1	2·2
	8	0·6	0·3	1·4	1·4	1·9	1·5	1·2
Mean ..	..	1·0	1·0	1·7	2·1	1·9	1·8	1·6
On Skids	3	0	0	0·4	0	2·5	1·0	0·6
	5	0·3	0·3	2·2	2·0	1·2	0·5	1·1
	6	0·4	0·2	0·2	0·1	2·2	1·8	0·8
	7	0·6	0·5	3·1	2·4	0·6	1·7	1·5
	8	0·3	1·2	0	2·2	1·3	2·0	1·2
Mean ..	..	0·3	0·4	1·2	1·3	1·6	1·4	1·0

stained than those on the skids. The anomalies appearing in the table (e.g. log 2 on ground) are probably due to varying degrees of susceptibility of the respective logs, which could be the result of differences in the relative moisture or nutrient contents. Because only a limited number of logs was available, only one log could be cut each week and consequently no mean could be arrived at for any individual period.

Period and Amount of Bluestain Development in the Open.

For this experiment 18 logs were available. Of these 12 were placed on the ground and six on skids in cleared country. Observations (see Table 3) showed that stain penetration effects were similar for the two positions except that penetration tended to be greater on the upper than the lower surface in both cases. This no doubt is due to the quicker drying conditions of the upper surface producing a more favourable moisture content for fungal growth.

Table 3.

STAIN PENETRATION IN LOGS LEFT IN THE OPEN ON THE GROUND AND ON SKIDS.

Position.	Weeks from Felling to Milling.	No. of Logs.	Mean Depth of Stain Penetration (Inches).						Mean.
			Under Surface.	Upper Surface.	Butt Under.	Butt Upper.	Top Under.	Top Upper.	
On Ground	5	6	0·6	0·9	2·2	2·7	2·4	3·2	2·0
	8	6	0·6	1·6	4·4	3·8	3·1	3·3	2·8
On Skids	8	6	1·1	1·5	3·7	4·2	2·8	3·2	2·8

The infection over the same period and at the same time was much more severe than in either those placed at the scrub ramps or those left in the rainforest (Tables 1 and 2). The warming of the logs by the sun in the open may have produced a more suitable incubation temperature for the development of the fungus than existed at the relatively well-protected scrub ramps, and the conditions of drying may also have more quickly reduced the moisture content of the wood to a suitable figure for fungal growth.

Effect of Direct Contact with an Infected Log on Possibility and Degree of Infection of Clean Logs.

For this purpose three logs only were used; one of these was badly bluestained, the others clean and newly felled.

These logs were stored on the ground at the scrub ramps. It is evident from the table that contact with the infected log had no effect on side penetration. The end penetration, however, appeared to be greater, though this need not necessarily have been due to the presence of the infected log.

Table 4.

Stain Penetration in Clean Logs in Contact with an Infected Log.

No. of Logs.	Weeks from Felling to Milling.	Mean Depth of Stain Penetration (Inches).						Mean.
		Under Surface.	Upper Surface.	Butt Under.	Butt Upper.	Top Under.	Top Upper.	
2	8	0·9	0·7	4·9	4·6	2·7	4·4	·0

Value of Various Chemical and Physical Methods of Control.

Six treatments were used in this series and for each treatment four logs were obtained and left at the stump in the rain-forest (Plate 2) and two logs were hauled to the scrub ramps and treated in an identical fashion (Plates 3 and 4). The six treatments were:—

1. "Lignasan."
2. Bordeaux mixture.
3. Creosote–soap emulsion.
4. "Quartzite"–arsenic mixture.
5. Bark on with creosote-vaseline paint on cut ends.
6. Bark on with clean ends.

Plate 2.

Hoop Pine Logs Treated at the Stump in the Rain-forest.

Plate 3.

HAULING A HOOP PINE LOG FROM THE RAIN-FOREST TO THE RAMPS FOR TREATMENT.

Plate 4.
Treated Hoop Pine Logs on the Ground at the Scrub Ramps.

It was essential that the treatments chosen should be easy of application, enabling the logs to be sprayed in the field. The soda solutions which have in places been employed with some success were not used because of the high temperatures at which the solutions must be maintained. A spray for use on logs under rain-forest conditions should be capable of being applied cold, and should be easy to prepare and to apply. The four sprays chosen were selected because they represented divergent groups of fungicides.

In all cases where two logs were obtained from the same tree a different treatment was applied to each log in order to compensate in some degree for any individual differences which might be present in the trees. The distribution of the logs in the rain-forest was also made as varied as possible for each treatment. This was relatively easy as the trees from which the logs were cut were distributed over several acres of natural forest in broken country.

In the case of the spray treatments the logs were treated immediately after felling and barking, and were spun with a cant-hook in order that all surfaces, including the ends, might be thoroughly sprayed by means of a knapsack sprayer. In preparing the spray mixtures, water from the nearest of the numerous creeks in the area was used. The logs which were treated at the scrub ramps were hauled into position by bullocks as soon as possible after cutting. In the case of the two treatments in which the bark was left on the logs all of the logs were left in the rain-forest at the stump because of the difficulty of hauling hoop pine logs in their bark over the ground. Untreated control logs were used in all cases for purposes of comparison.

The logs were left in position for from five to eight weeks, with an average of seven weeks, after treatment to the time of milling.

"Lignasan" Solution.

"Lignasan," as used, is an ethyl mercury chloride compound which is soluble in cold water. The mixture was prepared according to the directions supplied with the product—that is, "Lignasan" was dissolved at the rate of one pound of "Lignasan" in 40 Imperial gallons of water. In practice it was found that one gallon of the solution was sufficient to thoroughly treat 130 square feet of log surface.

On inspection the logs treated with "Lignasan" presented a clean, glazed, whitish surface. In the rain-forest (see Table 5), "Lignasan" exercised much more effective control over sapstaining fungi than any of the other treatments. The untreated controls showed bad "blueing." Similarly at the scrub ramps "Lignasan" was more effective than the other treatments represented there.

Table 5.

STAIN PENETRATION IN LOGS AFTER VARIOUS CHEMICAL AND PHYSICAL TREATMENTS.

Treatment.	In the Rain-forest.		At Scrub Ramps on Ground.	
	No. of Logs.	Penetration (Mean Depth—inches).	No. of Logs.	Penetration (Mean Depth—inches).
"Lignasan" solution	4	0·1	2	0·8
Bordeaux mixture	4	0·3	2	1·9
Creosote–soap emulsion ..	4	0·65	2	1·9
"Quartzite"–arsenic mixture	4	1·7	2	2·4
Bark on (sealed ends)	4	nil	..	..
Bark on (ends bare)	14	10·9 (ends only)	..	..
Control	8	1·6	2	2·7

Bordeaux Mixture.

Bordeaux mixture was used as a representative of the copper group of fungicides. It was prepared according to the 6-4-40 formula and a resin-soda sticker was mixed with the spray at the rate of one gallon of sticker to 25 gallons of spray. It was found that one gallon of Bordeaux spray as prepared above was sufficient to cover 110 square feet of log surface. The spray gave the logs a bluish appearance which persisted on the surface of the sapwood on the cut ends of the logs up to the completion of the experiment but faded on the longitudinal surface, where spray penetration was less.

The Bordeaux mixture treatment of logs in the rain-forest exercised considerable control over side penetration by sapstaining fungi, but the protection against end penetration was weak. Compared with the untreated control (Table 5) the treatment showed good results and also appeared in a favourable light when compared with the treatments with creosote-soap emulsion and with

"Quartzite"—arsenic mxture. The Bordeaux mixture treatment compared with "Lignasan" treatment, however, was inferior in regard to both efficiency as a stain control and ease of preparation of the spray mixture.

The logs treated at the scrub ramps were badly "blued," evidencing adverse weathering qualities for the Bordeaux mixture as compared with "Lignasan."

Creosote-Soap Emulsion.

Creosote being a well known wood preservative, it was included as a treatment. Its staining effect would be no drawback in the case of unmilled logs, the surfaces of which are removed at processing. Because of the sappy wet state of the logs the creosote was applied as a water emulsion and soft soap was used as an emulsifying agent. After a number of trial mixes the following formula for preparing the emulsion was arrived at and proved sufficiently stable for its purpose:—

Creosote, 1 gallon;

Soft soap, 1 pound;

Water, 4 gallons.

The creosote used was that prepared according to the K55 specification of the Australian Council for Scientific and Industrial Research. The soap was first dissolved in water by kneading it by hand. The creosote was then added and the mixture pumped several times through the sprayer until a good yellow-brown emulsion was obtained. This emulsion proved to be stable during the time of application but had to be agitated again after the operator had walked to another site. One gallon of the spray was sufficient to thoroughly treat 110 square feet of log surface. The sprayed logs turned to a red-brown colour after treatment but became brown in a few days.

The logs treated with creosote-soap emulsion proved to be slightly better with regard to freedom from stain than the untreated controls and the "Quartzite"-arsenic treatment but not as good as the "Lignasan" and Bordeaux mixture treatments. The logs at the scrub ramps were more severely stained than those left in the scrub, as was the case with the other treatments described. It appeared that the active constituents of the creosote were too volatile to have any lasting effect on the surface of a wet log. In addition, there was little or no penetration of the wood by the creosote and the dressing was partly washed off by rain within a short time.

"Quartzite"-Arsenic Treatment.

"Quartzite" is a meta-silicate of sodium and is said to be of some value as a controlling agent for sapstaining fungi in sawn timber. Previous work in connexion with borers in hoop pine logs indicated that "Quartzite" mixed with

arsenious oxide might be of value as a preventive of sapstain and borers, and accordingly the mixture was included as a treatment in this experiment. The mixture was prepared as follows:—

"Quartzite" 17 per cent. solution, 1 gallon;
Arsenious oxide, 3·2 oz.

In order to dissolve the arsenious oxide it was boiled with caustic soda in the proportion of one ounce of caustic soda to four ounces of arsenious oxide. The "Quartzite" was then diluted with water to make a 17 per cent. solution and the arsenic well stirred in. One gallon of the mixture was sufficient to cover 130 square feet of log surface. The spray set to a jelly-like substance on exposure and soon hardened to form a varnished surface. However, the surface proved to be an excellent substrate for various superficial fungi such as *Penicillium* spp. and within a few weeks the logs were completely covered with mould on the surface and borers attacked the logs during and after the first week from treatment.

On reference to Table 5 it will be seen that, if anything, the "Quartzite"-arsenic spray gave worse results than the untreated controls both in the scrub and at the scrub ramps and in addition to this the mixture is more difficult to prepare than any of the others in the experiment and has a corrosive action on the skin.

Bark on; Creosote-Vaseline Mixture on the Ends.

At times selected trees of good form are cut for the sake of obtaining the seed for plantation purposes before the logging area on which they stand is normally logged and the logs are wanted or can be got out of the forest for milling purposes. Consequently the logs may have to remain in the rain-forest for a considerable period until logging operations catch up to them. In order to preserve the timber in the trees it was decided to try leaving the logs in their bark at the stump and painting the cut ends with a mixture of equal parts of creosote (K55 specification) and petroleum jelly. Four logs were treated thus.

Reference to Table 5 shows that all the logs reached the mill in perfect condition after lying for eight weeks at their stumps in the rain-forest. There was no penetration of bluestain from the cut ends of the logs and the creosote had penetrated from the cut ends of the logs approximately one-eighth of an inch into the log at each end. All the logs were full of sap at milling and the treatment would appear to be an excellent one for the preservation of the timber of seed trees.

When the bark has been left on a hoop pine tree for some weeks after felling it tightens on the tree and becomes increasingly difficult to remove; moreover, the timber cutters must make another trip later to take the bark off. Both of these factors increase costs and as a general practice the procedure tested would be unsound, except for special cases such as seed tree felling as cited above.

Bark on; Ends Untreated.

For this purpose 14 logs were left with the bark on and the ends were left untreated. The logs were barked and milled after having been left lying at their stumps in the forest for periods of five and seven weeks.

The greatest penetration in any one log was 27 inches from one end. There was no staining in the bark-covered area. The results (Table 5) show how necessary it is to cover the ends of the log. The bark itself was an efficient covering over the length of the log.

Untreated Control Logs in the Scrub.

Eight logs were left untreated in the scrub and two were hauled to the scrub ramps and left on the ground.

Reference to Table 5 shows that all treatments with the exception of the "Quartzite"-arsenic spray gave better results than the untreated control. It is also again shown that logs hauled to the scrub ramps became more severely stained than those left in the rain-forest over the period of the experiment.

Conclusions.

The experiment was strictly of an observational nature. Bluestain is most severe in logs left outside the rain-forest in the open and logs left at the scrub ramps on the rain-forest edge are worse stained than those left to lie where they fall in the rain-forest.

Logs placed on skids contain a greater volume of stained timber than those in the same location on the ground.

In the case of logs left on the ground the upper side of the log contains more stained timber than the under side.

Bluestain, under the conditions of the experiment, did not seriously affect untreated logs in the rain-forest, for immediate milling purposes, until the fourth week, though end penetration was evident in the second week.

Some trees appear to possess an individual resistance to bluestaining due to an unknown factor or factors probably related to moisture and nutrient content.

Of all the spray treatments used, "Lignasan" gave the best results, with Bordeaux mixture, creosote-soap emulsion and "Quartzite"-arsenic mixture following in that order. The untreated controls were less stained than those logs treated with "Quartzite"-arsenic mixture, though more so than those sprayed with other mixtures.

Logs left with the bark on and the ends painted with a creosote-vaseline mixture remained clean throughout the experiment. Those left with the bark on and the ends untreated showed considerable end penetration of the bluestaining organisms.

In all cases the penetration of the stain was greater from the ends of the logs than from the sides.

SECOND SERIES OF EXPERIMENTS.

Because of the promising results given by "Lignasan" treatment, the initial experiment was followed up by a series of treatments with this product in order to obtain further information concerning the effectiveness of the fungicide as a control for bluestain. With this object in view three distinct treatments were designed, viz.:—

(1) The logs were sprayed immediately after felling and barking, and were milled at different periods after treatment. This was to determine how long "Lignasan" remained effective over the time of the experiment.

(2) The logs were treated immediately after felling and barking and resprayed at later intervals in order to find if a second treatment at some particular period after the first would check any bluestaining coming in due to the weakening of the first treatment.

(3) The logs were felled and barked and then sprayed at varying intervals after barking in order that some estimate of the period in which active infection first takes place after barking might be determined.

Treatment 1.

For the purposes of this treatment 12 logs were available. Six of these were left untreated as controls and the remaining six were treated with "Lignasan" immediately after barking. Three weeks after barking the first log was milled and thereafter one was milled each week to the seventh week, when two were milled. The corresponding control logs were milled at similar intervals.

Table 6.

STAIN PENETRATION IN LOGS TREATED ONCE WITH "LIGNASAN."

Treatment.	No. of Logs.	Mean Depth of Penetration in Inches at Various Intervals.				
		3 Weeks.	4 Weeks.	5 Weeks.	6 Weeks.	7 Weeks.
"Lignasan"	6	nil	nil	nil	nil	nil
Control	6	nil	0·6	0·4	0·7	1·3

From Table 6 it will be seen that "Lignasan" proved to be a perfect control for bluestain over the period of the experiment while the control logs became progressively worse in regard to discolouration. This showed that "Lignasan" remained active on the logs for at least seven weeks under the conditions obtaining, while in the control logs staining was evident from the fourth week onwards when the second control log was cut.

Treatment 2.

Fourteen logs were used in this experiment (Table 7) and of these four were left untreated as controls while 10 were used for treatment purposes. The logs were treated immediately after felling and barking and six were left with but one treatment while the remaining four were retreated once at intervals of one week between logs.

Table 7.

STAIN PENETRATION IN LOGS TREATED TWICE WITH "LIGNASAN."

Treatment.	Mean Depth of Penetration in Inches after 5 Weeks. Logs Resprayed as Shown.					
	Unsprayed.	One Spray.	Resprayed.			
			1 Week.	2 Weeks.	3 Weeks.	4 Weeks.
"Lignasan"	..	nil	nil	nil	nil	nil
Control	0·8	..	..	..	..	..

On referring to Table 7 it will be seen that one spraying gave as effective control of bluestaining over the period of the experiment as two sprayings. The controls showed considerable staining over the same period.

Treatment 3.

Fourteen logs were available for this experiment and of these four were left as controls and 10 were used for treatments. The treatments were carried out immediately after barking, four hours after barking, 24 hours after barking, two days after barking and seven days after barking.

Table 8.

STAIN PENETRATION IN LOGS SPRAYED WITH "LIGNASAN" AT VARIOUS INTERVALS AFTER FELLING AND BARKING.

Treatment.	Immediately.	4 Hours.	24 Hours.	2 Days.	7 Days.	No Treatment.
Mean Depth of Penetration (inches) ..	nil	0·1	0·1	0·7	0·5	0·8

Reference to Table 8 will show that staining was present in logs treated four hours after barking but did not become serious until after 24 hours had elapsed between barking and treatment. Treatment after an interval of two days appeared to be useless, as the fungus had penetrated beyond reach of the spray when applied at that time.

Conclusions.

No advantage accrues from treating the logs a second time at an interval after the first treatment, since a single treatment gives effective control for seven weeks.

Logs treated later than 24 hours after barking become seriously stained.

THE BLUESTAINING ORGANISM.

A series of pure culture isolations from stained timber obtained from the experimental logs established the identity of the causal organism of the bluestaining as *Diplodia pinea* (Desm.) Kickx. This fungus was also isolated from bluestained timber of slash pine (*Pinus caribaea*) obtained from thinnings from plantations at Beerwah (Queensland). This fungus has also been identified as the causal organism of sapstaining of *Pinus radiata* timber in New Zealand (Birch, 1936).

BORER INCIDENCE IN TREATED LOGS.

Though the experiments were designed to provide information regarding bluestain alone, a number of observations concerning borers were made and it appears from literature on the subject that borers and bluestain can be directly correlated inasmuch as both presumably depend for their existence on the food reserves of the living wood cells at the time of felling. For this reason the majority of the borers were found only in the sapwood.

In the case of many logs borer attack was apparent within 14 days after felling and became progressively worse up to milling. In a few cases borer attack was noted seven days after felling; this was chiefly in the logs treated with "Quartzite"-arsenic mixture and in the control logs. It also occurred in logs subjected to other treatments with the exception of creosote-soap emulsion, in which case the borers entered the logs in the fourth week. In one or two instances the borers had entered from the ends of the logs but in the vast majority of cases entry was gained through the sides. It was very evident that "Lignasan" did not in any way act as a borer deterrent and though "Lignasan" might save the logs from degrade due to bluestaining an equal amount of degrade was brought about by borer infestation.

The logs left with the bark on were uniformly free of borers. The species of borers observed during the experiment were:—

Platypus australis Chap.
Crossotarsus omnivorous Lea.
Platypus froggatti Samp.
} fam. Platypodidae.

Xyleborus testaceus Walk., fam. Scolytidae.

The most prevalent species were the last three, with the second and third being the most plentiful.

Xyleborus pseudosolidus Schedl. (fam. Scolytidae) was also found in a few cases but had evidently attacked the living tree. It had also penetrated the true wood whereas the other species listed only attacked the sapwood.

APPENDIX.

WEATHER DATA FOR PERIOD OF BLUESTAIN EXPERIMENT.

Date.	Rainfall.	Dew.	Temperature °F.		Relative Humidity Per Cent.	
			Maximum.	Minimum.	9 a.m.	3 p.m.
1935.						
January 17	..	Light	89	71	82	..
January 18	60	..	91	71	81	..
January 19	..	..	83	67	72	..
January 20	..	..	..	..	..	..
January 21	..	Light	87	60	72	..
January 22	2	..	85	66	85	..
January 23	..	..	85	61	73	..
January 24	..	..	88	66	95	..
January 25	..	Medium	..	..	..	51
January 26	..	Medium	89	63	63	..
January 27	..	..	..	..	..	..
January 28	..	..	89	65	78	..
January 29	..	..	95	67	82	..
January 30	18	Light	85	68	86	60
January 31	49	..	93	65	95	..
February 1	..	Light	93	72	82	57
February 2	15	..	93	72	90	..
February 3	..	..	..	..	..	..
February 4	..	Light	95	59	86	76
February 5	..	Light	92	72	86	70
February 6	14	..	95	67	81	54
February 7	..	..	89	63	76	68
February 8	..	..	..	..	..	..
February 9	..	Medium	91	67	90	..
February 10	..	Medium	..	..	..	..
February 11	145	Light	93	67	91	100
February 12	152	Heavy	92	69	95	75
February 13	4	Heavy	91	64	80	70
February 14	18	..	91	65	90	52
February 15	6	Heavy	85	65	90	53
February 16	..	Heavy	91	65	76	..
February 17	..	..	..	..	..	..
February 18	10	Heavy	91	66	73	..
February 19	..	..	92	68	95	..
February 20	161	..	97	70	95	..
February 21	248	..	92	69	100	55
February 22	..	Medium	92	69	82	78
February 23	36	..	88	70	73	..
February 24	..	..	..	..	..	..
February 25	293	..	80	66	95	69
February 26	55	..	78	66	90	66
February 27	3	..	81	67	80	62
February 28	..	..	82	65	90	77

BLUESTAINED CASE TIMBER AND MOULD ROTS IN HEN EGGS.

By H. E. YOUNG, D.Sc.Agr., Pathologist, Science Branch, Division of Plant Industry.

SUMMARY.

It is demonstrated that mould rots in eggs can be artificially produced by infection with spores of a sap-staining fungus isolated from case timber.

Early treatment of eggs with the sodium salt of salicyl anilide was shown to be an effective preventive of decay in eggs caused by moulds under the conditions of the experiment but was ineffective against bacterial rots.

Trials involving various methods of handling showed that under normal export conditions bluestained hoop pine (Araucaria cunninghamii) timber has no effect on the quality of eggs when it is used as a case material.

INTRODUCTION.

In 1938 attention was called to the use of bluestained hoop pine timber in cases in which eggs were being packed for export overseas and fears were expressed that the mould responsible for the staining of the timber might cause rots in the eggs. If this proved to be so, it was likely that bluestained timber would be rejected for case-making, resulting in a loss to the timber trade and a higher-priced case due to the better grade timber which would be required.

INFECTION OF EGGS WITH TRICHODERMA LIGNORUM.

Isolations from affected timber supplied by the Queensland Egg Board revealed the presence of the fungi *Diplodia pinea* and *Trichoderma lignorum*. It has been demonstrated in England and America that various species of *Penicillium* are capable of causing black rots in eggs; and in America it was shown in one investigation that *Penicillium* and *Cladosporium* moulding developed only when unseasoned cases were used for storage and it was concluded that infection of the eggs might take place either before or during storage whenever moisture is present.

Keeping these facts in mind, it was decided to test the susceptibility of eggs to a strain of *Trichoderma lignorum* isolated from case timber. For this purpose, six fresh eggs were sprayed with spores of the fungus and held in a moist atmosphere. At the end of a fortnight, all eggs showed evidence of rots and *T. lignorum* was isolated from the spotted areas. In preliminary trials, it was found that in a saturated atmosphere infection did not readily occur but that with lower humidities, with enough moisture present to support fungus growth, infection occurred readily.

PREVENTION OF TRICHODERMA ROTS IN EGGS.

Salicyl Anilide as an Egg Preservative.

The literature on the prevention of egg deterioration by fungal infection was reviewed but there did not appear to be any practical treatment which was entirely satisfactory for eggs. In New Zealand, a satisfactory treatment for preventing mould in butter boxes and on cheeses had been used. This consisted in dipping the timber and the cheeses in a 0.1 solution of salicyl anilide (water-soluble) for 10 minutes and then drying.

It was thought worthwhile to try the effect of salicyl anilide on eggs and trials were accordingly initiated. The salicyl anilide used in this case was the commercial preparation "Shirlan AG," an insoluble form which is applied as a suspension in water. The concentration used was 0.5 per cent. by weight.

In a preliminary test it was found that dipping in "Shirlan AG" prevented infection in eggs subsequently sprayed with *Trichoderma lignorum* spores. The flavour of treated eggs was in no way different from that of normal eggs.

Following this test a larger scale experiment designed to test the efficacy of "Shirlan AG" as an egg preservative was initiated.

The experiment was conducted in two series. In one series the eggs were held in an export case at room temperature and examined at weekly intervals. In the other series, the case of eggs was held for six weeks (the approximate time of carriage to Great Britain) under cold storage conditions similar to those obtaining during transport overseas, and on removal were examined at weekly intervals for the appearance of rots.

Eggs Held at Room Temperature.

For the purpose of the room temperature holding experiment, 250 fresh eggs were obtained from the one farm in order to have a comparable series. On receipt, the eggs were mixed and then divided into lots of 50 to provide for 5 treatments. The treatments were as follows:—

1. Application of *Trichoderma* spores, then dipping in "Shirlan AG" on the same day.

2. Application of *Trichoderma* spores, then dipping in "Shirlan AG" 24 hours later.

3. Application of *Trichoderma* spores on receipt; no dipping.

4. Dipping in "Shirlan AG," followed by application of *Trichoderma* spores on the same day.

The *Trichoderma* spores were suspended in distilled water and sprayed on to the eggs with an atomizer. In treatment 1, the eggs were allowed to dry before dipping in "Shirlan AG." The dipping process consisted in washing each individual egg in a bath of "Shirlan AG" with the aid of a cottonwool wad.

After dipping, the eggs were allowed to dry on a rack and were then packed in clean cardboard egg containers and placed in the case. Where "Shirlan AG" was applied 24 hours after the spores (treatment 2), the eggs were kept moist in the interval in order to facilitate the action of any fungi. The control eggs were not washed at all.

All treatments were divided into two lots, each of 25 eggs, each lot was placed in a separate tray and the 10 trays were distributed at random in the case. The whole case was kept moist by means of spraying with sterile water once daily for three days.

After the commencement of the trial the eggs were candled at weekly intervals until the end of the experiment. The results were as shown in Table 1. From these results, it will be seen that the most prolific yield of rots was in treatment 3, in which *Trichoderma* spores were applied but no dipping was performed. There was no significant difference between treatments 2, 4 and 5, all of which, except 5, involved a treatment with "Shirlan AG." Treatment 1 had the lowest percentage of rots. The fact that the number of rots in the untreated eggs was similar to that in all the "Shirlan AG"-treated eggs was due to infection before treatment. Since the number of rots in the untreated eggs was slightly in excess of that for any "Shirlan AG" treatment, the conclusion was drawn that

Table 1.

NUMBER OF ROTS IN EGGS HELD AT ROOM TEMPERATURE.

Treatment.	Number of Rots each Week.							Total.	Percentage Rotten.
	1st	2nd	3rd	4th	5th	6th	7th		
1. Spores, then " Shirlan AG "	..	..	1	2	1	1	..	5	10
2. Spores, then " Shirlan AG " in 24 hours	..	..	2	4	2	3	1	12	24
3. Spores, no " Shirlan AG "	..	4	4	6	4	3	13	34	68
4. " Shirlan AG " then spores	..	..	2	3	2	3	1	11	22
5. Untreated	..	..	1	1	3	..	9	14	28

this excess was due to infections which had not developed enough to penetrate beyond reach of "Shirlan AG" at the time of the treatment. It follows that "Shirlan AG" was efficacious in preventing all mould rots when infection occurred after treatment or within 24 hours before treatment.

The organisms isolated from the rotted eggs were *Trichoderma lignorum* and *Clostridium* sp. Their percentage occurrence in the various treatments was:—

Treatment.	*Trichoderma.*	*Clostridium.*
	Per cent.	Per cent.
1	100	—
2	80	20
3	60	40
4	66	34
5	100	—

Eggs Held in Cold Store.

In order to test the efficacy of "Shirlan AG" under cold storage conditions, the experiment was repeated on similar lines but, after treatment, the eggs were held in a commercial cold store in Brisbane at a temperature of 34 degrees C. for six weeks and were examined weekly after removal from storage. The eggs were kept moist during the observation period by spraying with sterile water. It was noticeable that there was a copious condensation of moisture on the eggs and cases after removal from the cold room. In this experiment, the results of the weekly candlings were as shown in Table 2.

Table 2.

NUMBER OF ROTS IN EGGS HELD IN COLD STORE.

Treatment.	Number of Rots at Weekly Observations.					Total Rots.	Percentage Rots.
	1st	2nd	3rd	4th	5th		
1. Spores, then " Shirlan AG "	..	1	2	8	12	23	46
2. Spores, then "Shirlan AG" in 24 hours	..	..	2	4	19	25	50
3. Spores, no " Shirlan AG "	..	12	15	12	4	43	86
4. " Shirlan AG " then spores	..	5	6	7	7	25	50
5. Untreated	..	3	11	13	6	33	66

The results follow the same general trend as in the previous experiment except that no doubt owing to the moister conditions of storage the number of affected eggs was greater. The treatment involving spraying with *Trichoderma* spores alone gave the largest number of rots, the control was next highest and the treatments involving dipping had substantially fewer rots. The higher percentage in the control in this case was no doubt due to infection during the period of observation in the moist atmosphere. It will be seen that even under moist conditions "Shirlan AG" was able to control 36 per cent. to 40 per cent. of the subsequent infection. The isolations from affected eggs revealed the presence of *Trichoderma* and *Clostridium* again in the untreated eggs in the proportion of four *Trichoderma* to three *Clostridium* infections and of one *Trichoderma* to one *Clostridium* in the "Shirlan AG" treatments. No other bacterial or fungal isolates were found.

Eggs Treated on the Farm.

As a further test an experiment was carried out on a poultry farm at Noosa in south-eastern Queensland. The treatments were:—

A. Farm-washed (abrasive soap and water).

B. Washed with 0.5 per cent. "Shirlan AG" in water.

C. Unwashed.

Each treatment was applied to 108 fresh eggs. The "Shirlan AG" treatment consisted in soaking the eggs in the fungicide for approximately three minutes. The eggs after six weeks in cold storage were delivered to the laboratory for weekly examinations, with results as shown in Table 3.

Table 3.

NUMBER OF ROTS IN FARM-TREATED EGGS.

Treatment.	Number of Rotten Eggs at Weekly Inspections.							Total No. Rots.	Percentage Rotten.
	1st	2nd	3rd	4th	5th	6th	7th		
A. Farm washed	..	2	9	7	7	8	15	43	44
B. Washed with "Shirlan AG" in water ..	2	1	9	17	21	13	16	79	63·1
C. Unwashed	..	1	1	..	6	2	1	11	10·1

In this case the eggs were again kept moist by spraying with distilled water. It will be noted that the worst results in this experiment were obtained from the "Shirlan AG" treatment and the best from non-washing, with the farm-washing procedure intermediate between the two. Isolations from the eggs revealed the presence of five bacterial rots to every fungus rot. Only *Trichoderma lignorum* was found amongst the fungal rots and the bacteria were all bacilli.

It is considered that, in the concentration used, "Shirlan AG" has no effect on bacterial growth and the relatively long period of immersion in the washing water in the "Shirlan AG" treatment was instrumental in distributing the bacteria, originating in the excreta and dirt, over the surface of the eggs and into the pores of the shell, thus considerably increasing the percentage of rotten eggs. The ordinary farm-washed eggs, being wetted in the washing water for a shorter period than in the "Shirlan AG" treatment, consequently received less infection. The keeping qualities of the unwashed eggs were, in this case, outstanding.

SHELL POROSITY AND INFECTION.

In the course of the experiments described above it was decided to see whether there was any marked correlation between shell porosity and infection. In order to determine porosity, the eggs were placed in a gentian violet solution in water and held under a vacuum of $7\frac{1}{2}$ lb. for three minutes and then allowed to absorb the stain. Porosity was indicated on breaking by the blue spots on the interior of the shell. Susceptibility to infection appeared to be correlated with the number of spots. The size of the spots did not appear to have great significance. This is explained by the fact that the large spots were not indicative of large shell pores but of small clusters of pores of normal size.

CASE TIMBER AS A SOURCE OF MOULD CONTAMINATION.

Following on the series of experiments in which "Shirlan AG" was shown to be effective as a mould preventive, attention was given to the possibility

of *Trichoderma* infection of eggs being caused by bluestained timber in egg cases. An experiment involving the following treatments was conducted.

1. Bluestained cases; eggs treated with "Shirlan AG."
2. Bluestained cases; eggs untreated.
3. Bluestained cases; treated with "Shirlan AG"; eggs untreated.
4. Bluestained cases treated with "Shirlan AG"; eggs treated also.
5. Clean case treated with "Shirlan AG"; eggs treated also.
6. Clean case treated with "Shirlan AG"; eggs untreated.
7. Clean case untreated; eggs untreated.
8. Clean case treated with "Shirlan AG"; eggs treated 24 hours after collecting.

The type of case used was that known to the trade as the "aeroplane" case, and one case containing 100 eggs was used for each treatment. The cases were obtained freshly made from the case manufacturers, those for the bluestain treatments being made from particularly badly stained timber. The clean cases showed no evidence of sapstain. The fillers used in the cases were the standard type of strawboard export fillers. Clean, unused fillers were used in all the cases.

The "Shirlan AG"-treated cases were immersed for three minutes in a 0·5 suspension of the fungicide and then dried.

The eggs were obtained in the Brisbane district from a commercial egg-producing farm, with a good record as to the quality of eggs submitted to market and with the capacity to provide all the eggs required in two gatherings. The eggs were gathered on the farm and treated and packed on the same day, except for the last treatment, when the washing was carried out 24 hours after gathering.

The procedure carried out at treatment was to wash the eggs by hand in the "Shirlan AG" mixture instead of in water. The eggs were then allowed to dry on a draining rack before packing.

On the completion of treatment and packing, the eggs were stored in cold rooms at a temperature of 35·0 degrees F. for six weeks. After the completion of the cold storage period, the eggs were removed to the ordinary store rooms, where the temperature varied from 65 degrees to 70 degrees F. Examinations were conducted by the Queensland Egg Board's graders at weekly intervals for three weeks. The fourth and final observations were carried out by a Poultry Expert of the Queensland Department of Agriculture and Stock with the assistance of the writer. After the fourth examination, the experiment was concluded because under normal circumstances all eggs removed from cold storage should have been consumed before four weeks had elapsed.

The results noted at the weekly gradings and obtained from the grading charts supplied by the Queensland Egg Board, together with the results of the final examination, were as shown in Table 4.

Table 4.

WEEKLY CONDITION OF EGGS FOR FOUR WEEKS AFTER COLD STORAGE.

Treatment.	1					2					3					4				
Condition.	G1.	G3.	C.	B.S.	B.	G1.	G3.	C.	B.S.	B.	G1.	G3.	C.	B.S.	B.	G1.	G3.	C.	B.S.	B.
Weekly Inspection																				
First	94	2	4	..	..	98	..	2	..	..	95	..	4	..	..	96	1	3	..	..
Second ..	94	2	4	..	..	98	..	2	..	..	95	1	4	..	..	95	1	3	..	1
Third	93	1	5	..	1	98	..	2	..	..	93	1	4	..	1	94	1	2	..	2
Fourth ..	93	1	5	..	1	98	..	2	..	..	93	1	4	..	1	94	1	2	..	2

Treatment.	5					6					7					8				
Condition.	G1.	G3.	C.	B.S.	B.	G1.	G3.	C.	B.S.	B.	G1.	G3.	C.	B.S.	B.	G1.	G3.	C.	B.S.	B.
Weekly Inspection																				
First	94	2	3	..	1	98	1	..	..	1	96	3	..	..	1	92	2	2	..	4
Second ..	93	2	4	..	1	98	1	..	..	1	96	3	..	..	1	89	2	5	..	4
Third	90	2	6	..	2	97	1	..	1	1	96	3	..	..	1	87	4	5	..	4
Fourth ..	90	2	6	..	2	97	1	..	1	1	96	3	..	..	1	87	4	5	..	4

G1 = Grade 1 ; G3 = Grade 3 ; C = Cracked ; B.S. = Blood Spot ; B = Bad.

NOTE.—Grade 1 eggs were good but could not be sold as fresh owing to deterioration due to ageing. They were suitable for culinary purposes.

From the figures supplied in the table, it will be seen that there was no significant difference between the eggs in any treatment. No mould rots were found in any of the eggs noted as bad; the majority of these had "stuck" yolks. Only two eggs, one in treatment 5 (third week) and one in treatment 1 (third week), had bacterial rots. The eggs relegated to grade 3 were placed there on account of the condition of "watery white" or "ruptured membrane." It will be seen that in the whole experiment only two eggs showed typical decay caused by bacteria and none caused by mould. From this it was concluded that bluestained hoop pine cases, even when so badly stained as to be culled out at the case mill, had no effect on the keeping quality of eggs.

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